Appendix E

TAMIAMI TRAIL MODIFICATIONS BENEFITS ANALYSIS PROCEDURES

MWD Tamiami Trail Modification
Benefits Analysis Procedures
August 2005 (updated October 24, 2005)

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Introduction

Representatives from six agencies (SFWMD, ENP, USFWS, Florida FWCC, FDEP, and USACE) participated in the Tamiami Trail Modification (TTM) Benefits Workshops held 23-26 May 2005 and 6-7 July 2005 in Jacksonville, Florida. The team included engineers, hydrologists, and biologists. The TTM project area includes the 10.7-mile length of Tamiami Trail (U.S. 41) between S-333 (near L-67 Extension) and S-334 (near L-30 and L-31N) and the downstream Northeast Shark River Slough (NESS) of Everglades National Park.

The goal of the benefits analysis was to identify the hydrologic and ecological conditions that would occur with alternative lengths of conveyance (equal to bridge length) from the L-29 Borrow Canal adjacent to Tamiami Trail to Northeast Shark River Slough (NESS). These conditions would be evaluated and compared to identify quantitative benefits for each alternative.

The team used a variety of sources of information during its analysis. These included historical photos and surveys produced before Tamiami Trail was constructed in the 1920s, data on flows through Tamiami Trail bridges and culverts in the 1940s, and current topographic information. The team also reviewed computer model predictions from the Natural Systems Model (NSM) version 4.6, South Florida Water Management Model (SFWMM) runs for several of the Combined Structural and Operational Plan (CSOP) alternatives, and RMA-2 modeling of bridge lengths in Tamiami Trail. The team also borrowed from the analyses contained in the 2003 General Reevaluation Report (GRR) for Tamiami Trail Modification, the associated 2003 U.S. Fish and Wildlife Service Coordination Act Report, and a May 2005 Draft Tamiami Trail Alternative Optimization Report prepared by the Everglades National Park (ENP report).

The ENP report integrated much information and addressed more ecosystem components than the other recent reports, but it contained some assumptions that reduced its direct applicability for this Tamiami Trail RGRR, as follows.

1. The purpose of the RGRR for the Tamiami Trail component of the Modified Water Deliveries Project is to identify appropriate conveyance of water from the L-29 canal to Northeast Shark River Slough to meet the authority and objectives of the Modified Water Deliveries Project, and the necessary modifications Tamiami Trail highway to provide this conveyance. The ENP report went further to state that this hydraulic conveyance

involves the reconnection of marshes in WCA-3B to marshes in NESS. However, the Corps maintains that the purpose of the Tamiami Trail Modification component of MWD consistent with the authorization is only the conveyance of water from the L-29 canal under Tamiami Trail to NESS. Reconnection of the marshes in WCA-3B and the marshes of NESS is a very worthwhile goal but beyond the authority of the study. This reconnection is part of a proposed Decompartmentalization project of CERP.

2. The ENP report's results assume that wherever a bridge would be constructed in Tamiami Trail, the corresponding parallel section of the L-29 levee would also be removed. Removal of sections of the L-29 levee is part of the proposed Decompartmentalization (Decomp) project of CERP and not part of the MWD project. The final decision whether to remove sections of the L-29 levee will be made during the Decomp alternatives formulation and analysis process. WRDA 2000 prohibits implementing Decomp until MWD is complete.
3. The report used different SFWMM CSOP runs to represent different Tamiami Trail bridge alternatives. This is not appropriate because
   - The SFWMM does not include or simulate bridge lengths.
   - Alternative CSOP model runs include different upstream structures, operations, and flow volumes to the L-29 canal and Tamiami Trail. These differences confound a determination of whether changes are due to Tamiami Trail bridges or to one or more of the upstream differences.
4. The CSOP alternative run assigned to represent the Tamiami Trail 3,000-foot bridge alternative had lower flow volumes than the CSOP alternative assigned to represent the 4-mile alternative, thus causing the 3,000-foot bridge alternative to show fewer flow benefits. All bridge alternatives must be analyzed using the same input flows to the L-29 canal.

Even with the concerns listed above, the ENP report still contained the greatest amount of information and detailed analysis potentially applicable to the comparison of Tamiami Trail Modification alternatives. The interagency team used the report's findings as the team's baseline and focused on ways to make adjustments and correct for some of its invalid assumptions, and produce predictions that allowed valid comparisons among alternatives, while staying within the policy and legal constraints on the project.

The team went through the following sequence of steps: screen performance measures that could not be used, add additional performance measure, apply the same flows to all alternative that were used for the 4-mile and 10.7-mile alternatives, estimate values for the 4-mile east alternative by extrapolation from the values for the 4-mile central alternative, assign numerical scoring to the qualitative raw values, estimate rate of change, and estimate the acreage in NESS where the changes would occur. Four alternatives were assessed during the May workshop and five additional alternatives were assessed during the July workshop.

A subteam then worked with the scores, rates of change, and area to: normalize the scores, multiply by area to produce habitat units, factor in the rate of change, calculate the habitat unit benefit for each alternative as the difference between the with-alternative condition and future without project condition, and calculate the average annual benefit for a 50-year period of analysis.

Screen Performance Measures

The team considered the 33 performance measures displayed in the ENP report, removing the following from further consideration in the RGRR because of the concerns discussed above.

The following 11 performance measures were removed because the differences they showed among alternatives resulted from different upstream operations of structures rather than bridge lengths.

1. Restore historic distribution of flows to ENP (% of flows west of L-67 extension)
2. Restore historic flow volumes to ENP
3. Restore historic overland flows from WCA-3A to WCA-3B
4. Restore historic overland flow volumes to NESS
5. Restore historic sheet flow conditions to NESS
6. Eliminate discontinuity in water levels above and below Tamiami Trail
7. Reduce water depths in WCA-3A
8. Reduction in Minimum flow and level (dry season depths) violations in NESS
9. Reduction in Minimum flow and level (dry season depths) violations in mid-NESS
10. Improve alligator nesting numbers and distribution
11. Reduce concentration of total phosphorus discharges to ENP from L-67A canal

The following five performance measures were removed because they depended on removing the section of the L-29 levee adjacent to a proposed bridge, rather than on bridge length

1. Reconnect historic slough habitats between WCA-3B and NESS
2. Increase physical connectivity of marshes between WCA-3B and ENP
3. Shift to open water, spikerush marsh and slough communities in NESS
4. Reduce encroachment of sawgrass and wet prairie vegetation into ENP and WCA-3B sloughs
5. Increase extent of slough vegetation communities

The following five performance measures were removed for other reasons

1. Reduce risk of ridge and tree island peat burning in Rocky Glades. This was very similar to reduce risk of ridge and tree island peat burning in NESS, which was retained
2. Four water quality performance measures: reduce injurious effect of organic forms of carbon, nitrogen, and phosphorus; increase dissolved oxygen; reduce specific conductance and sulfate concentration; increase nutrient cycling and uptake by biota. Differences in water quality were not clearly linked with bridge alternatives.

Two performance measures were revised: deep sloughs reconnected – important for both dry and wet seasons, and connectivity of ENP to flows in L-29 canal.

One new performance measure was developed for east west distribution of flows into ENP from L-29 canal.

The 13 PMs address important characteristics of ENP: hydrology, ridge & slough processes, vegetation, and wildlife. These 13 PMs reflect differences among alternative bridge lengths, and are not dependent on removing the L-29 levee or on different upstream operations.

Consistency of Models for Alternatives

The team recognized that the 3,000-foot alternative was assessed with lower flow volumes than were used for the other, larger alternatives. The team reassessed and re-estimated some performance measure values for the 3,000 alternative with the same CSOP West Bookend (WBE) alternative flows that were used for the other Tamiami Alternatives. The WBE was also used for all of the alternatives in the RMA-2 modeling of surface water velocities and flow directions.

The ENP report did not quantify the predictions for 4-mile East alternative in the same manner as for the 4-mile Central alternative or the other alternatives. The team initially assumed that many of the predictions for the central location would apply to the eastern location. The PM values were then adjusted as necessary based on known differences such as topography, vegetation, and wildlife resources and on model outputs.

Description of the Performance Measures

This section presents a brief description of each of the 13 performance measures – what they represent, how they were developed, the input information, units of measure, and the methods of calculation or estimation of values. The performance measures are placed into four groups for convenience. Values for all of the 13 performance measures are contained in ***Table 1*** which follows the text descriptions.

1. Restore water deliveries to ENP
A. Average Annual Flow Volumes
B. Proportion of area with low flow velocity (<0.1 f/s) discharges within 1 mile of Tamiami Trail
C. Connectivity of L-29 Canal and NESS as percent of total project length
D. Distribution of flows, east to west

2. Restore Ridge and Slough Processes
A. Reverse filling in of sloughs
B. Difference between average velocity in marsh and average velocity at road
C. Flows from L-29 Canal into deep sloughs of NESS

3. Restore Vegetative Communities
A. Shift to open water, spikerush marsh and slough communities in NESS
B. Risk of ridge and tree island peat burning in NESS
C. Invasion of exotic woody plant species

4. Restore Fish and Wildlife Resources
A. Total abundance of fishes in ENP marshes
B. Conditions for wading bird foraging and nesting
C. Reduction in wildlife mortality

PM 1.A. Average Annual Flow Volumes

This measure presents the annual volume of water passed through the culverts and proposed bridges in the Tamiami Trail alternatives. These flows entering the L-29 canal are controlled by precipitation, upstream structures, and operation of the structures. For the Tamiami Trail Modification RGRR, all alternatives were evaluated using the operations and flow volumes of the West Bookend Alternative of the Combined Structural and Operational Plan (CSOP) for the Modified Water Deliveries to Everglades National Park (MWD ENP) and the C-111 Canal projects. This volume is 683,000 acre feet per year across a transect extending across the approximately 11 mile project area (between L-67 extension and L-31N). The estimate of flows across this transect in the Natural System Model (NSM Version 4.6) is 895,000 acre feet per year.

There are ecological benefits to delivering more water to ENP than under existing and No Action conditions. The main purpose of this performance measure is to illustrate that the alternatives can accept the largest likely flows anticipated under Modified Water Deliveries project and that the No Action alternative can not pass this volume of water. If the same 683,000 acre feet per year of water were to be delivered to L-29 canal under the No Action condition, the small conveyance provided by the existing culverts would force the stage in L-29 canal to be high enough that Tamiami Trail would be damaged. A much smaller annual volume, 493,000 acre feet per year, is all that can safely pass under the existing and No Action condition.

PM 1.B. Area with high flow velocity (>0.1 f/s) discharges within 1 mile of Tamiami Trail, associated with structures

Information from South Florida Water Management District's recently constructed Stormwater Treatment Areas indicated that velocities greater than about 0.1 feet per second adversely affect vegetation colonization and growth. Sediment scouring is also increased.

Flows through Tamiami Trail culverts and proposed bridges have the potential to generate velocities greater than 0.1 feet per second as the water moves from the L-29 canal past the abutments of the proposed bridge(s) or from the L-29 canal through the existing culverts.

For each alternative the area with velocities above 0.1 feet per second was computed from the RMA-2 output. This allowed for a comparison of which alternatives would produce the least amount of impacted area.

These high velocity areas were all contained within a distance of 1 mile from the road. The performance measure value was calculated with the following formula:

1 – [(acres with velocity greater than 0.1 feet per second) / 6,848 acres]

6,848 acres is the number of acres in the 1 mile by 10.7 mile zone immediately south of Tamiami Trail. The performance measure represents the proportion of the one-mile wide zone that has velocity less than 0.1 feet per second, which are considered good velocities. The potential values range between near zero and 1.0. The target value is 1.0.

Most of the acreage measurements are between near zero and 411. The values of the performance measure for the alternatives analyzed are between 0.9 and 1.0. The impacts are expected to be intense and significant in the locations where they occur. However, the impacts occur over only a small geographic area and small proportion of the area of ENP.

No Action	**3,000-ft**	**2 Bridge: 2-Mi W, 1-Mi E**	**2 Bridge: 1.3-Mi W, .7-Mi E**	**3 Bridge: Ea 3000-ft**	**1 Bridge: 2 Miles**	**1 Bridge: 3 Miles**	**4-Mile Central**	**4-mile East**	**10.7-Mile**
	Alt 9	Alt 14	Alt 15	Alt 16	Alt 13	Alt 12	Alt 10	Alt 11	Alt 17
area within 1 mile of Tamiami Trail with high velocity (<0.1 f/s), acres									
187	**411**	**295**	**300**	**330**	**220**	**181**	**98**	**105**	**8**
PM 1.B. Proportion of area within 1 mile of Tamiami Trail with low flow velocity (<0.1 f/s)									
0.973	**0.940**	**0.957**	**0.956**	**0.952**	**0.968**	**0.974**	**0.986**	**0.985**	**0.999**

PM 1.C. Connectivity of L-29 Canal and NESS, percent of total project length (Connectivity_PM.xls)

This performance measure describes the connection between the L-29 canal and NESS. If the L-29 levee is removed under a future project, then this performance measure will also represent the connection between WCA 3B and NESS. This is an evolution and improvement of a simple lineal length of opening measurement. Modeled flow patterns clearly show that water spreads out in a fantail shape at the ends of the bridge. Ecological connectivity north and south of Tamiami Trail also follows this same fan pattern shown by the hydrology.

The connection length is the length of the bridge plus a 1,000 foot width on either side of the bridge. This connected length is then divided by the total width of eastern Shark Slough (from L-67 Extension to the L-31N levee) and expressed as a percentage. The calculations account for and prevent overlapping (double counting) and do not add “extra” connectivity by extending beyond the eastern and western limits of the project area. Movements of water and individuals are not limited to a straight line north-south path.

A 100% value indicates full connectivity and is the target.

Alternative	Bridge(s)	Connectivity PM	Length of Opening Ratio
17	10.7 M	**100%**	93%
10	4M Center	**39%**	36%
11	4M East	**39%**	36%
14	2MC & 1ME	**34%**	27%
12	3M	**30%**	27%
15	1.3MC & 0.7ME	**25%**	18%
16	3 3,000 feet	**25%**	15%
13	2M	**21%**	18%
9	3,000 feet	**8%**	5%

PM 1.D. Distribution of flows, east to west (Flow_Distribution_PM.xls)

Under pre-development conditions, there were no barriers to flow such as Tamiami Trail. Water flowed across a widely distributed, broad front. Water flowing southward was not directed to one or a small number of channels or openings. This Distribution of Flows, East to West performance measure describes how well the water flowing south from L-29 canal under Tamiami Trail is distributed in the east to west direction relative to the distribution that would occur if the highway was not in place.

This PM uses the flows from the RMA-2 modeling and then tracks the percent deviation from the 10.7 mile bridge flows using approximately 11 one mile wide sections. This performance measure gauges how well the bridge length and location(s) in combination with the culverts match the more natural distributions as represented by the full bridge length alternative.

The method calculates the percent deviation for each approximately one mile wide transect and then calculates a flow weighted (using the 10.7-mile bridge flows) total deviation. This deviation expressed in percent is subtracted from 100% to express how well the alternatives distribution matches the complete bridge distribution. Higher values represent a more restored condition.

A 100% value indicates flow distribution completely consistent with the 10.7-mile bridge.

PM 2.A. Reverse filling-in of sloughs

This PM is not directly proportional to bridge length, but is related to the alignment of the bridge with existing degraded sloughs south of Tamiami Trail as revealed by the USGS High Accuracy Elevation Data (HAED). Siting a bridge directly upstream of a degraded slough would maximize the potential for storm flow velocities to scour out sediments that have been accumulating in the sloughs since Tamiami Trail was constructed. The length of the bridge has relevance only to the extent that it can encompass more sloughs within its flow cross-section. The alternatives were scored on a scale of 0-7 as follows.

No Action = 0: The assumption is that the culverts would be kept at the FDOT max stage limitation of 7.5 feet. Therefore, flows through the culverts would be a continuation of existing conditions that are resulting in slough degradation.

3000-foot = 1: Minimally better than culverts - potential flow into only one slough.

10.7-mile = 7: This represents maximum potential for restoration of sloughs.

4-mile Central = 5: Would direct flows into five sloughs.

4-mile East = 5: Would direct flows into six sloughs, but they are more seriously degraded with less potential for restoration.

3-mile = 4: Would direct flows into three sloughs, including the deepest.

2 mi West + 1 mi East = 4: Would direct flows into four sloughs, but the ones on the east are less susceptible to restoration.

2-mile = 3: Would direct flows into two sloughs.

1.3 mi West + 0.7 mi East = 3: Would direct flows into two sloughs.

3 x 3000-foot = 2: Would direct flows into three sloughs, but only the westernmost one has a high potential for restoration.

PM 2.B. Difference between average velocity in marsh and average velocity at road

This performance measure describes how closely the water velocities near the road match the marsh velocity at a distance approximately 6,000 feet downstream of the road. The ideal situation is for the bridge to have marsh like velocities from the bridge south. The higher velocities that the shorter bridge produces are destructive to the ridge and slough environment immediately south of the Tamiami Trail.

The velocity at the center of the bridge for each alternative was compared against each alternative for a distance of approximately 6,000 feet downstream of the road. This analysis looked at the 1- and 100-year return frequency discharges. The data for this performance measure - estimated velocities at the road for each alternative - are derived from RMA-2 model runs. The average velocity in the marsh that is used in the calculations for all alternatives is 0.024 feet per second.

Ratio: (average velocity in marsh) / (average velocity at road in center of bridge opening)

High velocities near the road result in low values for the PM. For example, a ratio of 0.5 would represent a velocity at the road that is 2x the velocity in the marsh, and a ratio of 0.1 would represent a velocity at the road that is 10x the velocity in the marsh. Velocities near the road that are close to the velocities in the marsh have a high value approaching 1.0. Values range from zero to 1.0. The target for this performance measure is 1.0.

PM 2.C. Flows from L-29 Canal into Deep Sloughs of NESS
(Identification_of_Major_Slough.NEW.20051015_baf.xls)

While the existing culverts provide a hydraulic connection to the deeper sloughs existing within Northeastern Shark Slough (NESS) the capacity is not commensurate with amount of flow expected in these deeper sloughs during both high and low flow conditions. Preferential flow through these deeper sloughs is even more pronounced during drier times.

As can be seen in ***Figure 1***, the eastern portion of Shark Slough (from the L-67 extension to the L-31N levee) varies in elevation from about 5.6 feet NGVD to 7.2 feet NGVD. Without the obstruction of Tamiami Trail the preferential flow path from this varying elevation would be in the deeper sloughs. ***Figure 1*** shows the relative marsh capacity for a stage of 7.5 feet NGVD, which represents a typical transitional condition when the highest areas are only slightly inundated. The distribution of flow within northeast Shark Slough will become more uniformly distributed (from West to East) as depth increases and the relative depth differences reduce. The 7.5 feet NGVD stage is within two tenths of a foot the median value for the No Action and Alternatives 1 through 4 of the Combined Structural and Operational Plan (CSOP) for the Modified Water Deliveries to Everglades National Park (MWD ENP) and the C-111 Canal projects.

<u>Average and High Flow Conditions</u>

The stages in northeast Shark Slough range from about 4 feet NGVD (about 2 feet below ground surface) to 9 feet NGVD with a median stage of about 7.5 feet NGVD. As can be seen in ***Figure 1***, the stage of 7.5 feet NGVD results in an average depth of about 1.1 feet with a maximum depth of about 1.9 feet and a minimum depth of about 0.3 feet

The increased connection provided by the bridge aligned with deeper portions of northeast Shark Slough facilitates increased flow where it should occur preferentially. As can be seen in ***Figure 1***, with the water level less than 0.5 above the ridges most of the flow occurs in the deeper sloughs. It is important for water to be rapidly delivered to these deeper sloughs, commensurate with this capacity, during wet periods to produce higher velocities desirable for the redevelopment and maintenance of open water vegetation in these sloughs. This assessment assumes that sheet flow is based on the following equations

Manning Equation; $Q = (u/n)\ A\ Rh^{(2/3)}\ (hf / L)^{(1/2)}$
A depth dependent Manning n (n = ~ d -0.77)

Where:

A = Cross Section Flow Area = W * d
W = Flow Width
d = Flow Depth
P = Wetted Perimeter
R = Hydraulic Radium = A/P = (W * d) / W ~ d

Dry Conditions

During dry periods these deeper sloughs will have meaningfully deeper levels. The importance of these connections during drier periods is increased by the fact that both the existing condition and the expected range of the "with project" conditions (Tamiami Trail Bridge in conjunction with CSOP Operations) are drier than the desired conditions as represented by the Natural System Model (NSM). Specifically, NSM Version 4.6 predicts that the water levels would be at or below ground surface for approximately 2% of the time whereas as the existing conditions (ALT7R5) and alternatives (1 through 4) range from 8% to 11% of the time. The CERP reduces these dry conditions to 4% of the time. The increased connection that a bridge provides over culverts in terms of capacity and connectivity (sheet flow with low velocity versus flow through culverts) is expected, for the same water availability, to have the following benefits:

- Better distribution of the water; high water levels with more natural recession rates and less abnormal dry out as the limited water available can reach these sloughs.
- Facilitates the movement of fish into the L-29 canal through the deepest portions of Northeastern Shark Slough during dry outs which allows for rapid repopulation of these sloughs.
- Reduces unnatural predation around the culverts due to their limited area.

Evaluation Procedure

The benefits of different bridge lengths and locations were assessed considering each bridge location. A representative "marsh capacity" was estimated on 200 feet wide intervals using the USGS helicopter ground elevations and Manning's "n" based flow equation used in the South Florid Water Management Model (SFWMM). The location of each bridge is then used to calculate the marsh capacity directly connected by a bridge opening. This marsh capacity for the bridge is then divided by the marsh capacity of the approximately 11 mile wide northeast Shark Slough from the L-67 Extension to the L-31N levee (NAD83 horizontal coordinates from 763,500 to 821,250) and expressed as percentage. The full bridge option with 0.3 mile long ramps at each end (ending 0.3 miles West of S-334) had a total bridge length of 10.1 miles and encompassed 91% of the entire marsh capacity.

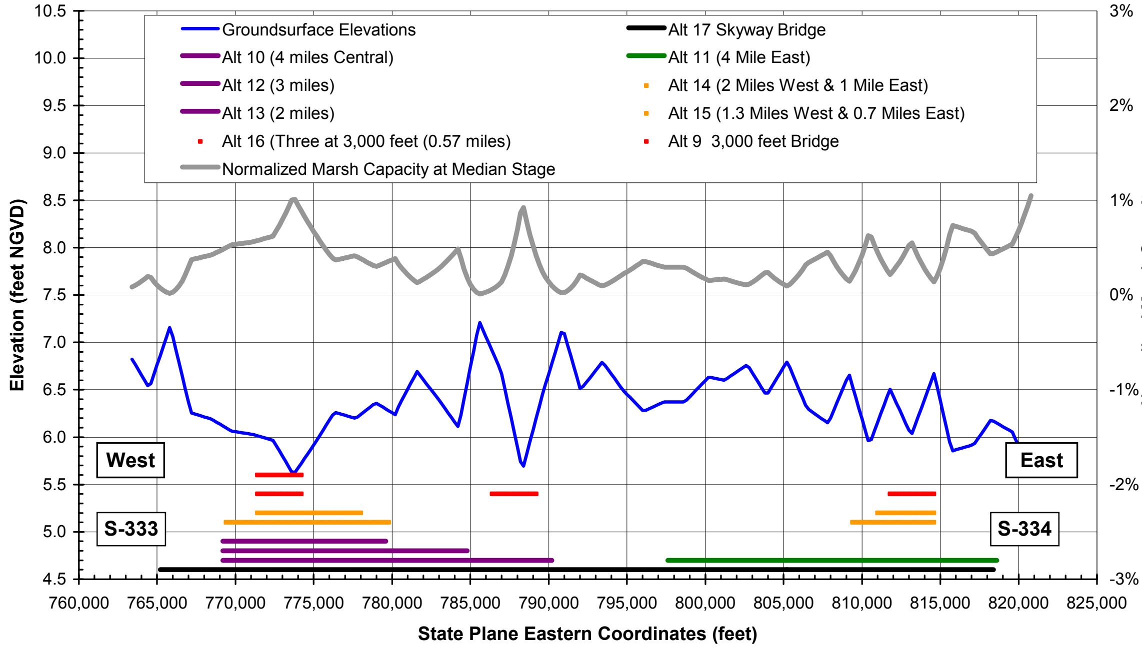


FIGURE 1
Proposed Bridge Locations and Normalized Marsh Capacity at the Median Stage of 7.5 feet NGVD

PM 3.A. Shift to open water, spikerush marsh, and slough communities in NESRS

NESRS historically was part of the ridge and slough (“corrugated”) Everglades landscape. Over the past 40 years of hydrologic isolation from the ecosystem to the north, it has largely converted to a drier community of mixed sawgrass. This PM evaluates the potential for alternatives to restore the historic landscape. It is driven by the depth and duration of flooding downstream of the bridges. The remnant sloughs on the eastern side of the project area are more degraded and therefore would be more difficult to be restored. There is also a greater number of remnant sloughs on the western side and there is historic information that pre-development flows through them were proportionately greater than would be indicated by their combined cross-section. Consequently, alternatives that are focused on flowing water through the west side are generally scored higher. Direct flooding of sloughs (immediately downstream of a bridge) is considered most beneficial because lateral flooding of adjacent sloughs will become truncated as seasonal flows diminish and interspersed ridges **isolate** southward flows. The bridge alternatives were scored on a scale of 0-7 as follows.

No Action = 0: The assumption is that the culverts would be kept at the FDOT max stage limitation of 7.5 feet. Therefore, flows through the culverts would be a continuation of the existing conditions that are degrading the sloughs.

3000-foot Bridge = 1: Minimally better than culverts – relatively narrow flow path directly floods only one slough.

10.7-mile = 7: This represents maximum potential for restoration of sloughs because it directly floods all the remnant sloughs.

4-mile Central = 6: This directly floods all the important remnant sloughs on the western side, but not directly those on the east.

4-mile East = 4: This directly floods all the eastern remnant sloughs, but was down-rated because those are less susceptible to restoration.

3-mile = 5: This directly floods fewer sloughs, so was down-rated from the 4-mile Central.

2 mi West + 1 mi. East = 5: This floods fewer sloughs on the west than the 3-mile, but picks up some on the east so it was scored the same.

2-mile = 4: This was down-rated from the 3-mile because it directly floods fewer sloughs.

1.3 mi West + 0.7 mi East = **3**: This directly floods fewer sloughs on the west and the east so was down-rated two points from the 2+1 bridge.

3 x 3000-foot = 4: Each of these bridges was positioned directly in front of a slough, so the three slough flooding represents an up-rating from the 1.3+0.7 bridge.

PM 3.B. Risk of ridge and tree island peat burning in NESRS

This PM is dependent on hydroperiod and whether the bridge delivers enough water to keep peat soils hydrated enough to minimize fire risk.

No Action = 2: The assumption is that the culverts would be kept at the FDOT max stage limitation of 7.5 feet. Therefore, flows through the culverts would be limited, but would provide some hydration of soils to limit burning.

3000-foot Bridge = 5: This minimal hydraulic bridge length would not curtail flows, but its narrow span would truncate lateral spread. This would cause earlier soil dry-outs at the eastern side of the project, so it was down-rated from the other bridge scores.

10.7-mile = 7: This represents the maximum potential to keep soils hydrated over the full cross section.

4-mile Central = 6: An intermediate length between 3000 and 10.7 was given the intermediate score.

4-mile East = 6: An intermediate length between 3000 and 10.7 was given the intermediate score.

3-mile = 6: An intermediate length between 3000 and 10.7 was given the intermediate score.

2 mi West + 1 mi. East = 6: An intermediate length between 3000 and 10.7 was given the intermediate score.

2-mile = 6: An intermediate length between 3000 and 10.7 was given the intermediate score.

1.3 mi West + 0.7 mi East = 6: An intermediate length between 3000 and 10.7 was given the intermediate score.

3 x 3000-foot = 6: An intermediate length between 3000 and 10.7 was given the intermediate score.

PM 3.C. Invasion of exotic woody plant species

This PM is dependent on two factors:

1) The alternative's capacity to keep the sloughs inundated to prevent exotic seedlings from invading.
2) The bridges length – the longer the bridge the greater number of exotic species that will be eliminated as the road embankment is removed for the bridge. This is considered less important than the inundation factor.

No Action = 2: The assumption is that the culverts would be kept at the FDOT max stage limitation of 7.5 feet, but flows through the culverts would still provide some capacity to keep the area inundated.

3000-foot Bridge = 4:

10.7-mile = 7: This would provide maximum potential for exotic control by removing all exotics along the highway and maximum inundation.

4-mile Central = 6: This was considered equivalent to the 10.7 mile for inundation, but was down-graded one point for shorter length.

4-mile East = 6: This was considered equivalent to the 10.7 mile for inundation, but was down-graded one point for shorter length.

3-mile = 5: This was down-graded one point from the 4-mile because of shorter length and slightly poorer inundation potential.

2 mi West + 1 mi. East = 5: This was considered equivalent to the 3-mile.

2-mile = 4: This was down-graded one point from the 3-mile because of shorter length and slightly poorer inundation potential.

1.3 mi West + 0.7 mi East = 4: This was considered equivalent to the 2-mile single span.

3 x 3000-foot = 4: This was considered equivalent to the 2-mile single span.

PM 4.A. Total abundance of fishes in ENP marshes

The PM is defined as being dependent on:

1) Lateral connection of sloughs through overflow from deeper sloughs improves fish access to micro-topographic relief refugia during dry-downs and increases hydroperiod within adjacent sloughs.
2) Longer bridge length increases pathways for fish dispersion and movement by improving and extending escape routes to L-29 Canal habitat during the dry season.

No Action = 0: The assumption is that the culverts would be kept at the FDOT max stage limitation of 7.5 feet. Therefore, flows through the culverts would be too small to reconnect any sloughs.

3000-foot Bridge = 1: Minimal benefit since it is not sited over a major slough.

10.7-mile = 7: This distributes water and biota laterally to the greatest extent.

4-mile Central = 5: This is down-rated from the 10.7 because fewer sloughs are spanned, resulting in less potential for lateral overflow to facilitate fish movement in response to drying conditions.

4-mile East = 5: This is considered equivalent to 4-mile West.

3-mile = 4: This was down-rated from the 4-mile because shorter length spans fewer sloughs.

2 mi West + 1 mi. East = 4: This is considered equivalent to 3-mile West.

2-mile = 3: This was down-rated from the 3-mile because shorter length spans fewer sloughs.

1.3 mi West + 0.7 mi East = 3: This is considered equivalent to 2-mile West.

3 x 3000-foot = 3: This is considered equivalent to 2-mile West.

PM 4.B. Conditions for wading bird foraging and nesting

This PM is based on the potential for restoring hydropatterns in NESRS to increase abundance and availability of forage fish that wading birds depend on for nesting success. Natural hydropatterns increase fish abundance and availability to wading birds during the crucial nesting period. Bridge alternatives on the east side of NESRS have reduced potential benefits for foraging wading birds because of limited microtopography leaving forage fish stranded over a shortened time period. Water delivered to western side is more beneficial to birds because water flows to the east side will dry out quicker due to degraded (shallower) sloughs and greater seepage. Deeper sloughs are preferred over shallower sloughs given that during the dry season the deeper sloughs are more likely to have continuous flows and during the wet season have overland flows. Bridges immediately adjacent to existing bird rookeries are less beneficial than bridge locations that include a buffer distance.

No Action = 0: The assumption is that the culverts would be kept at the FDOT max stage limitation of 7.5 feet. Therefore, flows through the culverts would be too small to see any beneficial effect.

3000-foot Bridge = 1: Minimal benefit since it is not sited over a major slough that would contribute to restored hydropatterns.

10.7-mile = 7: Allows for maximum potential restoration of hydropatterns.

4-mile Central = 5: Down-rated from 10.7 because shorter length has less potential for redistribution of flows restoring hydropatterns.

4-mile East = 4: Down-rated from 4-mile West because flows to the east are less beneficial due to the existing slough degradation results in shorter hydroperiods and earlier dry-out and because the bridge would be immediately adjacent to existing bird rookeries.

3-mile = 4: Considered equivalent to 4-mile East because shorter length is offset by presence of deeper sloughs.

2 mi West + 1 mi. East = 4: Considered equivalent to 3-mile by virtue of the same overall span length.

2-mile = 3: Down-rated from 3-mile because shorter length provides less potential to restore hydropatterns and no distribution of benefits to the east.

1.3 mi West + 0.7 mi East = 3: Scored equivalent to 2-mile by virtue of the same overall span length and distribution of benefits to the east.

3 x 3000-foot = 3: Considered equivalent to 2-mile by virtue of nearly the same overall span length.

PM 4.C. Reduction in wildlife mortality

This performance measure is based on average mortality data from USFWS for Tamiami Trail. The data describe an average of 261 deaths per mile of road per year and assumes that this rate applies to the entire 10.7 mile long project area.

The deaths of small animals from collision with automobiles would continue to occur on the sections of Tamiami Trail that would still be connected to the adjacent marsh and canal. The deaths would not occur on the bridged sections of Tamiami Trail because there would be no connection between the road surface and the marsh and canal habitat of the animals. The animals would not easily reach the road surface in these sections and then be at risk of being hit.

The performance measure presents the numbers of deaths that would be avoided because of the presence of the bridge(s). It is calculated by multiplying 261 deaths per mile per year by the total length of the bridge(s) in miles. A short bridge would only result in a small reduction in mortality while a bridge that spans the entire project area would produce the maximum value of 2,737 deaths per year avoided.

Performance Measures Values

The raw values for all of the performance measures described in the previous section are presented in ***Table 1***. The values for the performances measures were in many different units. Units included percent, feet, acres, acre-feet, feet per second, and scores of 0-7.

Calculating Habitat Units and Benefits

Although the Tamiami Trail PDT evaluated many performance measures to ascertain how well each of the alternative plans performed on various criteria indicative of ecosystem restoration, (e.g., average annual flow volumes, shift to open water, abundance of fishes in ENP marshes, and reverse filling in of sloughs), habitat units derived from the performance measures were selected by the PDT as the metric that best integrated information regarding the quality and quantity of improved hydrologic and ecologic function within the study area.

Sometimes it is difficult to summarize the results when the analyses are performed separately for distinct performance indicators. This phenomenon often occurs simply because different management measures or alternative plans "do" different things, provide different types of output, and provide benefits to different biological communities. This is true for the Tamiami Trail features and alternatives, in which certain performance measures quantify output in flows and hydrologic modeling output, and other performance measures examine ecological responses in a qualitative manner.

In order to estimate total benefits from the various alternatives, it is desirable to be able to perform CE/ICA on a metric that combines all performance measures output. Simply adding the performance measure output would be problematic, because the PM's operate at vastly different scales (i.e., two PM's only apply to a small geographic area), ecosystem responses to alternatives occur gradually through time, and the performance measures resources are represented in very different metrics (e.g., feet, acres, acre-feet, feet per second, percent, and qualitative measures). All three of these issues are addressed in the following description of the calculation of benefits.

The changes produced by each alternative were assessed over the same **acreage** of Northeast Shark River Slough, even though not all of the individual performance measures affected the same entire acreage. The area for analysis and comparison is defined by L-67 Extension on the west, Tamiami Trail on the north, and the L-31N and the 8.5 Square Mile Area (SMA) on the east. There is no firmly defined boundary on the south; the differences between alternatives and the without project condition gradually decrease as one moves south. For this study, the southern limit is defined by the team as an east-west line connecting the end of the L-67 Extension to 8.5 SMA. The total area is 63,195 acres. Eleven of the 13 performance measures apply to the entire 63,195 acres. Two of the 13 performance measures, 1.B and 2.B, only apply to the northernmost 1-mile wide by 10.7-mile long strip of land nearest Tamiami Trail, which totals 6,848 acres.

The team prepared a simple description of the changes in ecosystem conditions through **time** in response to the alternatives. The performance measures values and scores represent the ultimate, or end-point, of changes due to the alternatives, and the team recognized that the restoration of the entire area would not occur immediately after construction is complete. For the alternatives, the team estimated that 30 percent of the end-point would be achieved in the first year. Most of this represents the hydrological changes such as depth, velocity, and hydroperiod. The team further estimated that an additional six years, for a total of seven years, for the full extent of changes to occur. The herbaceous vegetation may take this long to fully respond to the hydrological changes. Fish and wildlife populations require a few seasons to respond to the changed hydrology and vegetation. Although not fully predictable, there is a good likelihood that a wet or dry year will occur during this period, further emphasizing the importance of incorporating events such as scouring some of the sediments and vegetation that have accumulated in the sloughs during high water events or connecting deep sloughs to the L-29 canal to maintain water during the lowest flow periods. The without project condition is proposed to remain the same throughout the period of analysis, the same as existing conditions. The period of analysis is 50 years, from 2010 to 2060.

The different **metrics** made it necessary to normalize the different PM's into a 0-1 index. The normalization method used was "percent of maximum", in which the maximum output achieved in each category by any of the alternatives was assigned a "1", and the output values for other alternatives for that same resource category were scaled as a percentage of that maximum (between 0 and 1). An index value of 1 would thus be assigned to an alternative that provides the maximum output value for the habitat unit categories, while a value of 0.5 would equate to the output value for an alternative that only provides 50% of the maximum output provided by the "largest" alternative (a hypothetical "largest" alternative in terms of delivering the maximum output of every habitat type). While other normalization techniques exist (e.g., percent of range, percent of total, unit vector), the percent of maximum is the most widely used technique and is usually the default method. Thus, a combined, normalized metric was calculated to perform CE/ICA on all outputs provided by the Tamiami Trail alternatives.

As an example of normalization, consider Performance Measure 1.A, average annual flow volumes. The goal is the NSM flow volume of 895 (ac-ft x 1,000), the flow that was established for each alternative was 683 (ac-ft x 1,000). The goal represents the maximum desired condition regarding the metric the PM measured. The normalization score for these alternatives resulted from dividing the goal by the alternative score and coming up with an index score. For the PM, the index score was the same for all alternatives and was .763. The no action condition for the PM was 493 (ac-ft x 1,000), and the index for the no action condition was calculated as .551. The basic methodology behind these calculations were held constant for each PM, with minor revisions to PM 1.B in which the lower the score the better had to be inversed, and PM 2.B where the PM was already an index reflecting a ratio. Index scores were calculated for all alternatives and for the no action condition. ***Table 1*** contains the raw value for each PM and alternative. ***Table 2*** includes the normalized value for each PM and alternative.

Habitat units were calculated by multiplying the indices by the acreages that were impacted by the PM's (PM 1.B and 2.B affected 6,848 acres, while the rest of the PM's affected the full 63,195 acres). The average annual calculation also takes into account that achievement of full performance is estimated to take seven years because the plant and animal resources only gradually respond to the physical changes generated by the alternatives. The average annual lift for each PM was calculated by subtracting the average annual habitat units for the no action plan from the average annual habitat units for each alternative. ***Table 3*** includes average annual Habitat Unit lift for each PM.

Each of the PM's were determined to be of equal importance, and were therefore all given a weight of "1" to be used to combine the habitat units associated with each PM. Since all of the habitat units occupied the same geographic area, an average of all the PM's was warranted. The averaging of the habitat units was a two-part process. It was first necessary to find the total habitat units of the upper section of the study area, and then the total habitat units of the lower section of the study area, and add these together to determine the total (HU) lift for the entire study area. This was necessary because two PM's only affect the upper 6,848 acres of the study area, while the rest of the PM's affected the entire study area. This 6,848 acre section accounts for 10.84% of the entire study area, so the process involved multiplying each of the 11 PM's that impacted the entire study area by .1084 and adding these habitat units to the two that impacted just the 6,848 acres. This total was then divided by 13 (due to 13 total PM's) to arrive at an average annual habitat unit lift for the upper section. The lower section only pertained to 11 PM's. These 11 PM's were multiplied by 89.16% to determine the habitat units that are associated with the lower section. Each of these figures were then added and the total was divided by 11 to arrive at the average annual lift of the lower section. The lower section and the upper sections average annual lift were then added to determine the total lift for the study area. This procedure ensured that no PM was double counted and the PM's that only affected the upper section of the study area were adjusted to reflect the lesser impact. ***Table 4*** includes the calculations for the upper and lower sections and the total habitat unit lift, or benefit, for each alternative.

Table 1: Raw Values for Performance Measures

2. Restoration	No Action	3,000-ft	2 Bridge: 2-Mi W, 1-Mi E	2 Bridge: 1.3-Mi W, .7-Mi E	3 Bridge: Ea 3000-ft	1 Bridge: 2 Miles	1 Bridge: 3 Miles	4-Mile Central	4-mile East	10.7-Mile Causeway
1 Restore water deliveries to ENP										
A. Flow Volumes, x1000 acre ft, goal 895	**493**	**683**	**683**	**683**	**683**	**683**	**683**	**683**	**683**	**683**
B. Proportion of area within 1 mile of Tamiami Trail with low velocity (<0.1 f/s)	**0.973**	**0.940**	**0.957**	**0.956**	**0.956**	**0.952**	**0.968**	**0.986**	**0.985**	**0.999**
C. Connectivity of L-29 Canal and NESS, percent of total length, %	**0**	**8**	**34**	**25**	**25**	**21**	**30**	**39**	**39**	**100**
D. Distribution of flows, east to west, %	**0**	**57**	**59**	**61**	**70**	**51**	**57**	**46**	**23**	**100**
2 Restore Ridge and Slough Processes										
A. Reverse filling in of sloughs	**0**	**1**	**4**	**3**	**2**	**3**	**4**	**5**	**5**	**7**
B. Difference between average velocity in marsh and average velocity at road, ratio	**0.014**	**0.137**	**0.455**	**0.345**	**0.238**	**0.455**	**0.500**	**0.556**	**0.556**	**1.000**
C. Enhance flows from L-29 Canal into deep sloughs of NESS, %	**0**	**11**	**39**	**27**	**23**	**30**	**37**	**45**	**34**	**91**
3 Restore Vegetative Communities										
A. Shift to open water, spikerush marsh and slough communities in NESS	**0**	**1**	**5**	**3**	**4**	**4**	**5**	**6**	**4**	**7**
B. Risk of ridge and tree island peat burning in NESS	**2**	**5**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**7**
C. Invasion of exotic woody plant species	**2**	**4**	**5**	**4**	**4**	**4**	**5**	**6**	**6**	**7**
4 Restore Fish and Wildlife Resources										
A. Abundance of fishes in ENP marshes	**0**	**1**	**4**	**3**	**3**	**3**	**4**	**5**	**5**	**7**
B. Conditions for wading bird foraging and nesting	**0**	**1**	**4**	**3**	**3**	**3**	**4**	**5**	**4**	**7**
C. Reduction in wildlife mortality, #/year	**0**	**148**	**783**	**522**	**455**	**522**	**783**	**1044**	**1044**	**2737**

Table 2: Normalized Indices for Performance Measures

2. Restoration	No Action	3,000-ft	2 Bridge: 2-Mi W, 1-Mi E	2 Bridge: 1.3-Mi W, .7-Mi E	3 Bridge: Ea 3000-ft	1 Bridge: 2 Miles	1 Bridge: 3 Miles	4-Mile Central	4-mile East	10.7-Mile Causeway
1 Restore water deliveries to ENP										
A. Flow Volumes	**0.551**	**0.763**	**0.763**	**0.763**	**0.763**	**0.763**	**0.763**	**0.763**	**0.763**	**0.763**
B. Proportion of area within 1 mile of Tamiami Trail with low velocity (<0.1 f/s)	**0.973**	**0.940**	**0.957**	**0.956**	**0.952**	**0.968**	**0.974**	**0.986**	**0.985**	**0.999**
C. Connectivity of L-29 Canal and NESS, percent of total length	**0.000**	**0.080**	**0.340**	**0.250**	**0.250**	**0.210**	**0.300**	**0.390**	**0.390**	**1**
D. Distribution of flows, east to west	**0.000**	**0.570**	**0.590**	**0.610**	**0.700**	**0.510**	**0.570**	**0.460**	**0.230**	**1**
2 Restore Ridge and Slough Processes										
A. Reverse filling in of sloughs	**0.000**	**0.143**	**0.571**	**0.429**	**0.286**	**0.429**	**0.571**	**0.714**	**0.714**	**1**
B. Difference between average velocity in marsh and average velocity at road	**0.014**	**0.137**	**0.455**	**0.345**	**0.238**	**0.455**	**0.500**	**0.556**	**0.556**	**1**
C. Enhance flows from L-29 Canal into deep sloughs of NESS	**0.000**	**0.110**	**0.390**	**0.270**	**0.230**	**0.300**	**0.370**	**0.450**	**0.340**	**0.91**
3 Restore Vegetative Communities										
A. Shift to open water, spikerush marsh and slough communities in NESS	**0.000**	**0.143**	**0.714**	**0.429**	**0.571**	**0.571**	**0.714**	**0.857**	**0.571**	**1**
B. Risk of ridge and tree island peat burning in NESS	**0.286**	**0.714**	**0.857**	**0.857**	**0.857**	**0.857**	**0.857**	**0.857**	**0.857**	**1**
C. Invasion of exotic woody plant species	**0.286**	**0.571**	**0.714**	**0.571**	**0.571**	**0.571**	**0.714**	**0.857**	**0.857**	**1**
4 Restore Fish and Wildlife Resources										
A. Abundance of fishes in ENP marshes	**0.000**	**0.143**	**0.571**	**0.429**	**0.429**	**0.429**	**0.571**	**0.714**	**0.714**	**1**
B. Conditions for wading bird foraging and nesting	**0.000**	**0.143**	**0.571**	**0.429**	**0.429**	**0.429**	**0.571**	**0.714**	**0.571**	**1**
C. Reduction in wildlife mortality	**0.000**	**0.054**	**0.286**	**0.191**	**0.163**	**0.191**	**0.286**	**0.381**	**0.381**	**1**

TABLE 3: AVERAGE ANNUAL HABITAT UNIT LIFT PER PERFORMANCE MEASURE

Restore water deliveries to ENP	Acres Impacted	3,000-ft	2 Bridge: 2-Mi W, 1-Mi E	2 Bridge: 1.3-Mi W, .7-Mi E	3 Bridge: Ea 3000-ft	1 Bridge: 2 Miles	1 Bridge: 3 Miles	4-Mile Central	4-mile East	10.7-Mile Causeway
A. Flow Volumes	63,195	12,745	12,745	12,745	12,745	12,745	12,745	12,745	12,745	12,745
B. Proportion of area within 1 mile of Tamiami Trail with low flow velocity (<0.1 f/s)	6,848	(213)	(103)	(107)	(136)	(31)	6	85	78	170
C. Connectivity of L-29 Canal and NESS, percent of total length	63,195	4,803	20,412	15,009	15,009	12,607	18,011	23,414	23,414	60,035
D. Distribution of flows, east to west	63,195	34,220	35,421	36,622	42,025	30,618	34,220	27,616	13,808	60,035
Restore Ridge and Slough Processes										
A. Reverse filling in of sloughs	63,195	8,576	34,306	25,729	17,153	25,729	34,306	42,882	42,882	60,035
B. Difference between average velocity in marsh and average velocity at road	6,848	798	2,864	2,150	1,456	2,864	3,160	3,521	3,521	6,413
C. Enhance flows from L-29 Canal into deep sloughs of NESS	63,195	6,604	23,414	16,210	13,808	18,011	22,213	27,016	20,412	54,632
Restore Vegetative Communities										
A. Shift to open water, spikerush marsh and slough communities in NESS	63,195	8,576	42,882	25,729	34,306	34,306	42,882	51,459	34,306	60,035
B. Risk of ridge and tree island peat burning in NESS	63,195	25,729	34,306	34,306	34,306	34,306	34,306	34,306	34,306	42,882
C. Invasion of exotic woody plant species	63,195	17,153	25,729	17,153	17,153	17,153	25,729	34,306	34,306	42,882
Restore Fish and Wildlife Resources										
A. Total abundance of fishes in ENP marshes	63,195	8,576	34,306	25,729	25,729	25,729	34,306	42,882	42,882	60,035
B. Conditions for wading bird foraging and nesting	63,195	8,576	34,306	25,729	25,729	25,729	34,306	42,882	34,306	60,035
C. Reduction in wildlife mortality	63,195	3,246	17,175	11,450	9,761	11,450	17,175	22,900	22,900	60,035

TABLE 4: AVERAGE ANNUAL HABIT UNIT LIFT FOR UPPER AND LOWER SECTIONS AND TOTAL AVERAGE ANNUAL HABITAT UNIT LIFT PER ALTERNATIVE

	3,000-ft	2 Bridge: 2-Mi W, 1-Mi E	2 Bridge: 1.3-Mi W, .7-Mi E	3 Bridge: Ea 3000-ft	1 Bridge: 2 Miles	1 Bridge: 3 Miles	4-Mile Central	4-mile East	10.7-Mile Causeway
Upper Section	15,632	36,908	28,754	28,173	29,758	36,791	42,891	37,882	68,738
Upper Section Averaged	1,202	2,839	2,212	2,167	2,289	2,830	3,299	2,914	5,288
Lower Section	123,760	280,855	219,700	220,871	221,459	276,573	323,123	281,983	511,233
Lower Section Averaged	11,251	25,532	19,973	20,079	20,133	25,143	29,375	25,635	46,476
Upper and Lower Section Total	12,453	28,371	22,185	22,246	22,422	27,973	32,674	28,549	51,763

Calculation of Average Annual Costs

Data for initial construction/implementation, land acquisition, monitoring, and periodically recurring costs for OMRR&R (operation, maintenance, repair, replacement, and rehabilitation), have been developed through engineering design and cost estimation, and real estate appraisal efforts. Details of that data development are explained and discussed elsewhere in this report. For economic evaluation of alternative plans on a comparable basis, these cost estimates are further refined through present worth calculations, use of appropriate price levels, and consideration of the timing of project expenditures.

Costs represent the difference between conditions without any plan (the “without-project condition”) and conditions with an alternative plan. For purposes of this report and analysis, NED costs (National Economic Development Costs, as defined by Federal and Corps of Engineers policy), are expressed in 2005 price levels, and are based on costs estimated to be incurred over a 50-year period of analysis. Costs of a plan represent the value of goods and services required to implement, operate, and maintain the plan.

The timing of when a plan’s costs are incurred is important. Construction and other initial implementation costs cannot simply be added to periodically recurring costs for project operation, maintenance, and monitoring. Also, construction costs incurred in a given year of the project can’t simply be added to construction costs incurred in other years if meaningful and direct comparisons of the costs of the different alternatives are to be made. A common practice of equating sums of money across time with their equivalent at an earlier single point in time is the process known as discounting. Through this mathematical process, which involves the use of an interest rate (or discount rate) officially prescribed by Federal policy for use in water resource planning analysis (currently set at 5.125% per year), the cost time streams of each alternative are mathematically translated into a present worth value. This present worth value, calculated for this study as of the beginning of the period of analysis (2010), can then be directly and meaningfully compared between the plans being considered in this study. An annual value, equivalent to the present worth, can also be computed for the 50-year period of analysis. This average annual value represents an equivalent way of expressing the costs of a plan. The various costs estimated to be incurred over time to put each plan into place and operating have been computed and expressed as both a present worth value and an average annual equivalent value. Corps guidance (ER 1105-2-100) requires that average annual equivalent costs be used for cost effectiveness and incremental cost analyses (CE/ICA).

In general, since all the alternatives effect some element of a 10.7 mile road span, the difference in costs for the various alternatives are due to different bridge lengths, number of bridges, number of access ramps, varying material and operational costs, and varying interest during construction (IDC) costs. Construction, real estate, IDC, total investment, present worth, and average annual equivalent costs for the Tamiami Trail alternatives are presented in ***Table5*** below.

The transportation O&M costs in the following table are calculated as a difference between the without-project condition and conditions with an alternative plan. In the case of Tamiami Trail, the O&M costs associated with the roadway are more expensive than the O&M costs associated with the bridge. This leads to a cost savings for O&M for each alternative, and the alternatives that have a greater bridge length have a greater cost savings. **Table 6** contains the future without conditions costs and the future with alternative costs used to determine the NED costs associated with O&M.

TABLE 5: CALCULATION OF COSTS USED IN COST EFFECTIVENESS ANALYSIS (Investment Costs)

	3,000ft	2 Mile / 1Mile	1.3 Mile / .7 mile	3 X 3,000ft	2 Mile	3 mile	4 Mile Cent	4 Mile East	10.7 Miles
Construction Cost	$68,300,000	$127,900,000	$104,100,000	$101,800,000	$99,300,000	$119,500,000	$141,400,000	$139,200,000	$278,000,000
PED & EDC (6%)	$4,098,000	$7,674,000	$6,246,000	$6,108,000	$5,958,000	$7,170,000	$8,484,000	$8,352,000	$16,680,000
S/A (8%)	$5,464,000	$10,232,000	$8,328,000	$8,144,000	$7,944,000	$9,560,000	$11,312,000	$11,136,000	$22,240,000
Total Construction	$77,862,000	$145,806,000	$118,674,000	$116,052,000	$113,202,000	$136,230,000	$161,196,000	$158,688,000	$316,920,000
Construction Schedule	36 Months	36 Months	36 Months	36 Months	36 Months	36 Months	36 Months	36 Months	36 Months
Real Estate	$1,511,000	$1,511,000	$1,511,000	$1,511,000	$1,511,000	$1,511,000	$1,511,000	$1,511,000	$1,511,000
Real Estate Schedule	39 Months	39 Months	39 Months	39 Months	39 Months	39 Months	39 Months	39 Months	39 Months
Total	$79,373,000	$147,317,000	$120,185,000	$117,563,000	$114,713,000	$137,741,000	$162,707,000	$160,199,000	$318,431,000
IDC Construction	$6,140,266	$11,498,390	$9,358,737	$9,151,963	$8,927,210	$10,743,218	$12,712,059	$12,514,276	$24,992,591
IDC Real Estate	$266,497	$266,497	$266,497	$266,497	$266,497	$266,497	$266,497	$266,497	$266,497
TOTAL INVESTMENT	$85,779,764	$159,081,888	$129,810,234	$126,981,461	$123,906,707	$148,750,716	$175,685,557	$172,979,773	$343,690,089
Transportation O&M	($50,564)	($316,961)	($188,491)	($160,030)	($188,491)	($316,961)	($381,152)	($381,152)	($1,026,564)
Conveyance O&M	$16,522	$18,602	$17,747	$17,494	$17,747	$18,602	$19,457	$19,457	$25,188
Period of Analysis	50	50	50	50	50	50	50	50	50
Annualization	$4,789,776	$8,882,825	$7,248,353	$7,090,400	$6,918,711	$8,305,953	$9,809,942	$9,658,857	$19,190,991
Total Annual Cost	$4,755,734	$8,584,467	$7,077,608	$6,947,863	$6,747,967	$8,007,594	$9,448,248	$9,297,162	$18,189,615

TABLE 6: CALCULATION OF COSTS USED FOR TRANSPORTATION O&M

	3,000ft	2 Mile / 1Mile	1.3 Mile / .7 mile	3 X 3,000ft	2 Mile	3 mile	4 Mile Cent	4 Mile East	10.7 Miles
Future Without	$2,502,802	$2,502,802	$2,502,802	$2,502,802	$2,502,802	$2,502,802	$2,502,802	$2,502,802	$2,502,802
Future With	$2,452,238	$2,185,841	$2,314,311	$2,342,772	$2,314,311	$2,185,841	$2,121,650	$2,121,650	$1,476,238
NED Cost	**($50,564)**	**($316,961)**	**($188,491)**	**($160,030)**	**($188,491)**	**($316,961)**	**($381,152)**	**($381,152)**	**($1,026,564)**

Cost Effectiveness and Incremental Cost Analysis

Cost effectiveness analysis begins with a comparison of the costs and outputs of alternative plans to identify the least cost plan for every level of output considered. Alternative plans are compared to identify those that would produce greater levels of output at the same cost, or at a lesser cost, as other alternative plans. Alternative plans identified through this comparison are the cost effective alternative plans. Next, through incremental cost analysis, the cost effective alternative plans are compared to identify the most economically efficient alternative plans, that is, the “Best Buy” alternative plans that produce the “biggest bang for the buck.” Cost effective plans are compared by examining the additional (incremental) costs for the additional (incremental) amounts of output produced by successively larger cost effective plans. The plans with the lowest incremental costs per unit of output for successively larger levels of output are the “Best Buy” plans. The results of these calculations and comparisons of costs and outputs between alternative plans provide a basis for addressing the decision question “Is it worth it?,” i.e., are the additional outputs worth the costs incurred to achieve them?

Although for Tamiami Trail many performance measures were evaluated to ascertain how well each of the alternative plans performed on various criteria indicative of ecosystem restoration, (e.g., average annual flow volumes, shift to open water, abundance of fishes in ENP marshes, and reverse filling in of sloughs), habitat units were derived from each performance measure and selected by the PDT as the metric that best integrated information regarding the quality and quantity of improved hydrologic and ecologic function within the study area. The basis for average annual output calculations was previously explained.

Cost effectiveness and incremental cost analyses were conducted for each of the Tamiami Trail alternative plans. These analyses compared the alternative plans’ average annual costs against the appropriate average annual habitat unit estimates. The average annual costs and outputs were calculated as the difference between with-plan and without-plan conditions over the period of analysis (through year 2060). Costs used for CE/ICA are displayed in ***Table5***. ***Table 2*** includes a list of the normalized value for each PM, ***Table 3*** includes average annual Habitat Unit lift for each PM and ***Table 4*** includes the calculations for the upper and lower sections and the total habitat unit lift, or benefit, for each alternative that was used in the CE/ICA.

The following table and figures represent the results of cost effectiveness analysis for the nine Tamiami Trail alternatives**.** ***Figure 2*** shows costs and outputs for all alternative plans. ***Table 7*** shows that the only two plans that are not cost effective are the 1.3 mile / .7 mile bridge combination and the three 3,000 ft bridges. ***Figure 2*** shows the cost effective and non cost effective plans.

FIGURE 2: TAMIAMI TRAIL ALTERNATIVE PLANS – CE/ICA RUN ON COMBINED AVERAGE ANNUAL HABITAT UNITS FOR ALL ALTERNATIVES

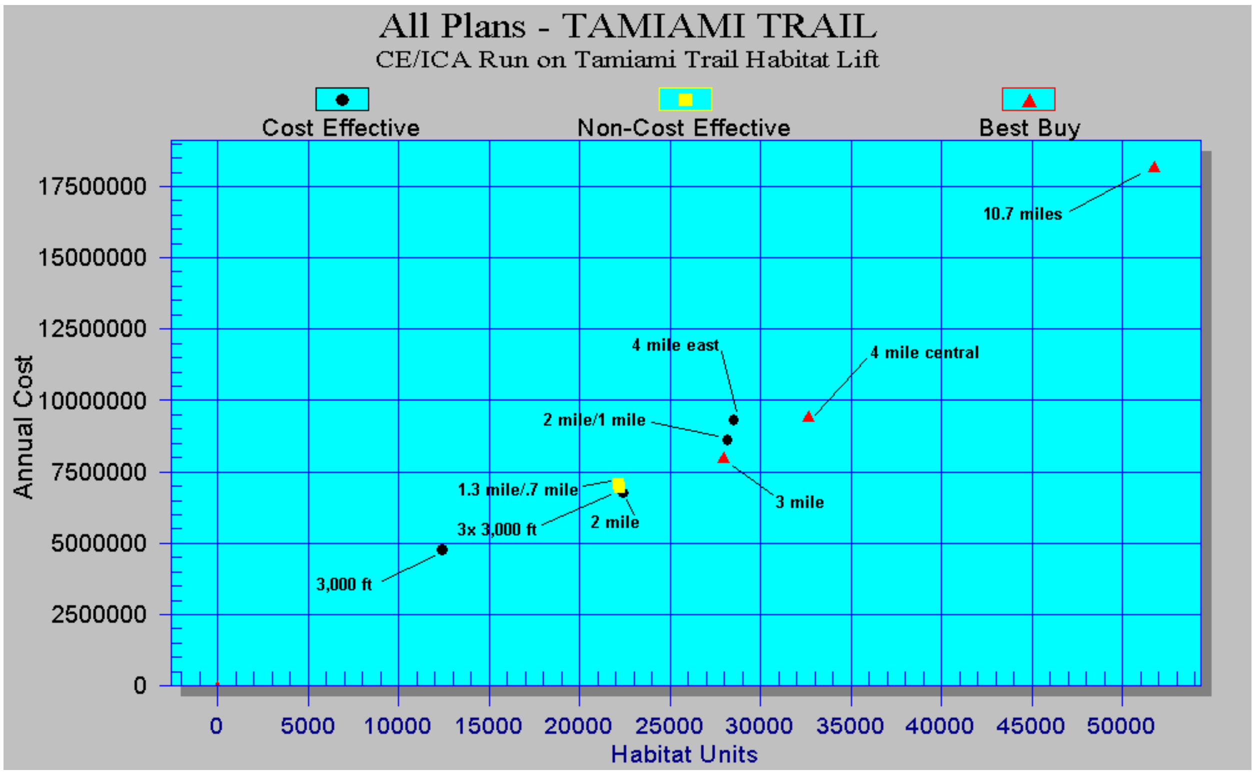


TABLE 7: RESULTS OF COST EFFECTIVENESS ANALYSIS ARRAYED BY INCREASING OUTPUT (ALL ALTERNATIVE PLANS)

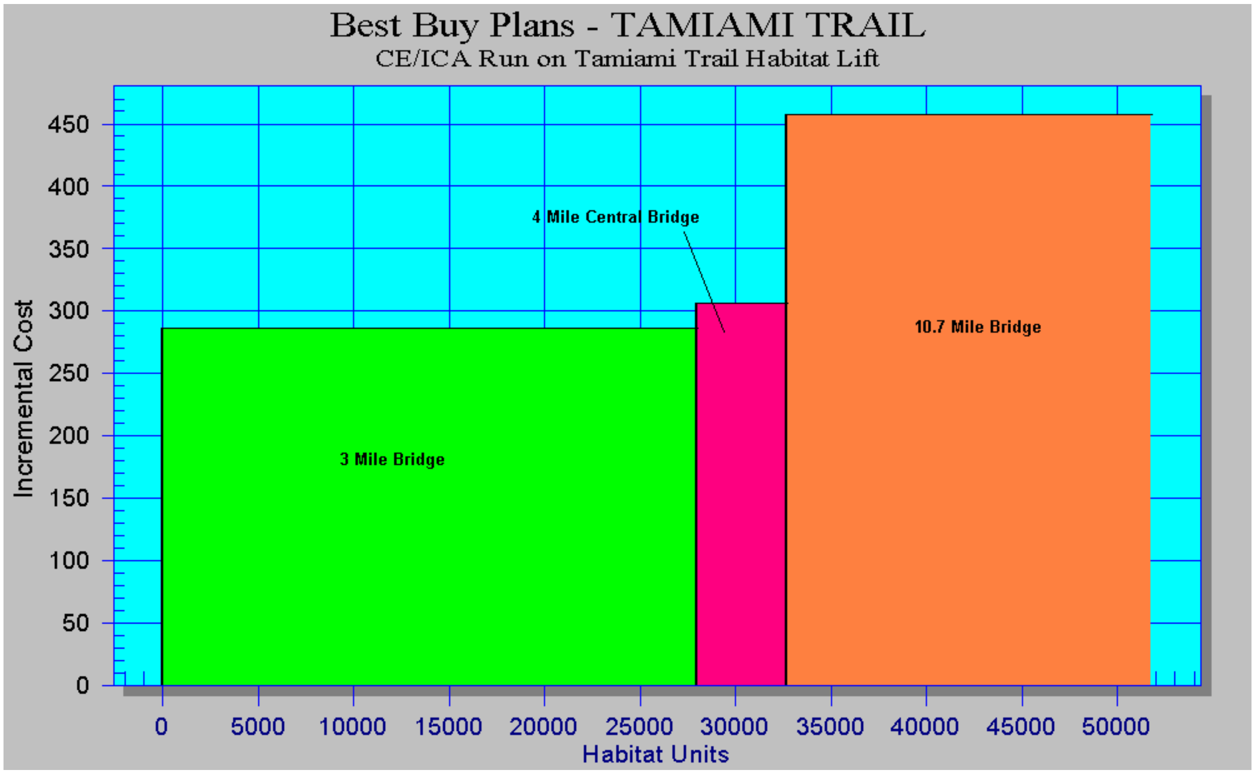
Alternative	Average Annual Cost	Average Annual Habitat Units	Average Annual Cost Per Average Annual Habitat Unit	Cost Effective
3,000ft	$4,755,734	12453	$382	YES
1.3 Mile / .7 mile	$7,077,608	22185	$319	NO
3 X 3,000ft	$6,947,863	22246	$312	NO
2 Mile	$6,747,967	22422	$301	YES
3 mile	$8,007,594	27973	$286	YES
2 Mile / 1Mile	$8,584,467	28371	$303	YES
4 Mile East	$9,297,162	28549	$326	YES
4 Mile Central	$9,448,248	32674	$289	YES
10.7 Miles	$18,189,615	51763	$351	YES

Next, incremental cost analysis was performed on these cost effective plans. ***Table 8*** shows the result of this. The first Best Buy plan, the three mile bridge, exhibits an incremental cost of $286 per habitat unit, delivering a total of 27,973 average annual habitat units. The second Best Buy plan, the four mile central bridge, delivers an additional 4,701 average annual habitat units at an incremental cost of $306 per habitat unit. The final Best Buy plan, the 10.7 mile bridge, provides an additional 19,089 average annual habitat units and an incremental cost of $457 per habitat unit. These results are displayed in ***Figure 3.***

TABLE 8: RESULTS OF INCREMENTAL COST ANALYSIS: COST EFFECTIVE & BEST BUY PLANS ARRAYED BY INCREASING OUTPUT FOR COMBINED HABITAT (ALL PLANS)

	Average Annual Cost	Output	Average Cost Per Output	Incremental Average Annual Cost	Incremental Output	Incremental Cost Per Output	Best Buy?
Without Plan	$0	0	N/A	N/A	N/A	N/A	
3 Mile Bridge	$8,007,594	27,973	$286	$8,007,594	27,973	$286	Best Buy
4 Mile Central Bridge	$9,448,247	32,674	$289	$1,440,653	4,701	$306	Best Buy
10.7Mile Bridge	$18,189,614	51,763	$351	$8,741,367	19,089	$457	Best Buy

FIGURE 3: TAMIAMI TRAIL BEST BUY PLANS – CE/ICA RUN ON ALL ALTERNATIVES



The single three mile bridge alternative is depicted as a best buy plan, while the 2 mile –1mile alternative is only considered cost effective, because the multiple bridge spans require more inclines and declines increasing the total cost by a great percentage than the benefits. There are public perception, acceptability, and uncertainty issues associated with the single span alternatives, however. CE/ICA is only one tool in selecting the recommended plan and many criteria can influence the decision making process.